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FISKERIDIREKTORATETS SKRIFTER
Serie Havundersøkelser
(Report on Norwegian Fishery and Marine Investigations)
Vol. XI. No. 4

Factors influencing the Size of the Year Classes in the Arcto-Norwegian Tribe of Cod

By
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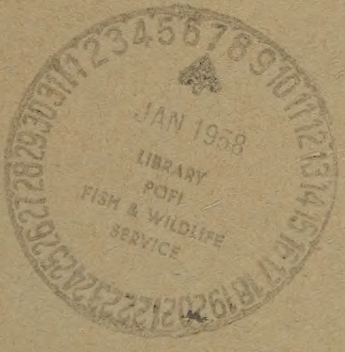

1957
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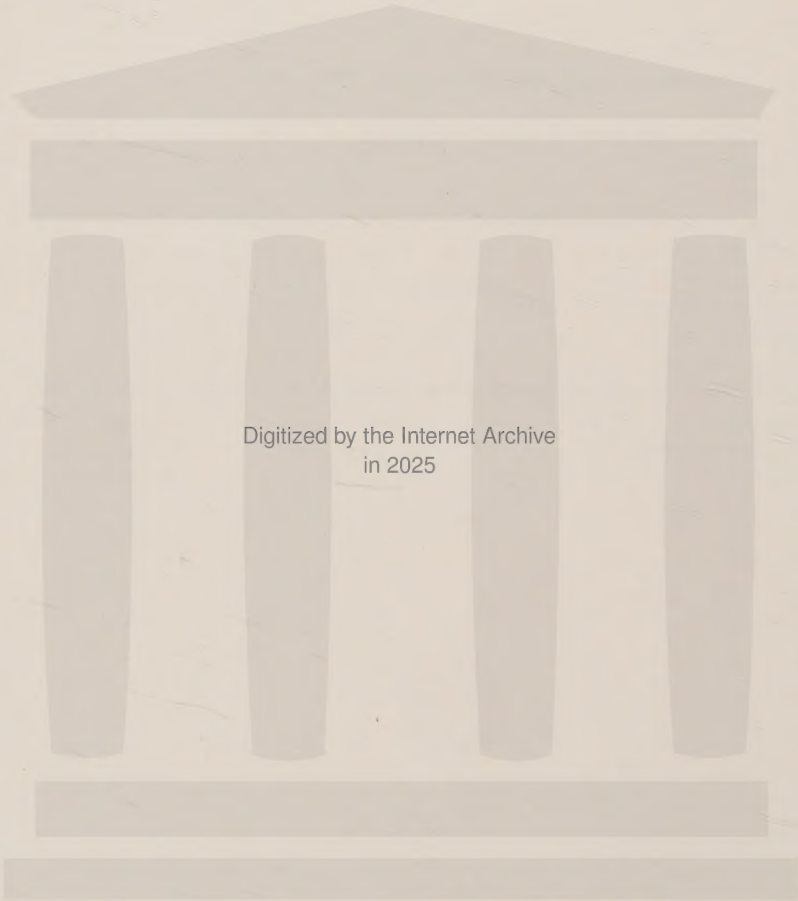

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INTRODUCTION

It is generally assumed that the size of a year class of fish is determined at an early stage in the life history. The theory was first forwarded by HJORT (1914, 1926). ROLLEFSEN (1930) suggested that in the Arcto-Norwegian stock of cod the size of a year class might already be determined during the egg stage. HJORT (1926) inferred that there were critical periods in the larval stage, 1) immediately after the yolk resorption, when lack of suitable food might cause mass mortality, 2) at a later stage, if the larvae by currents were carried too far into the ocean and did not succeed in reaching the shelf in time before the planktonic food in the sea died down during the autumn.

The idea of a «critical period» during the early life of marine fishes has hitherto been adopted by most fishery biologists. Recently MARR (1956) discussed the theory very thoroughly and on the basis of the information available came to the conclusion that there is little or no reason to believe that any periods during the larval life may be considered as critical or catastrophic, although the possibility cannot be entirely excluded, but the evidence points towards a survival at a constant rate, or at a constantly increasing rate.

DANNEVIG & HANSEN (1952) showed that cod larvae may live in filtered sea water, without any food, for several days after the yolk sack is resorbed, and still thrive when fed.

PARRISH (1950) found no relation between the brood density of the North Sea haddock and the egg production potential of the spawning stock. The same was stated for the Faroe haddock (SAVILLE 1956). A number of workers claim to have found a positive correlation between the number of postlarval fish and the size of the corresponding year class in the commercial catches (POULSEN 1931, 1944, RUSSELL 1935, KNUDSEN 1954, SAVILLE 1956).

In the present paper data are presented on the occurrence of eggs and larvae of cod in the waters of Northern Norway during a period of nine years, 1948—1956. An attempt is made to combine the observations with other data of biological and physical nature in order to elucidate some of the possible causes of the variation in size of the year classes in the commercial stock.

The author is very grateful to his collegues, Messrs. G. Sætersdal, O. J. Østvedt and O. Aasen for useful comments and criticisms. Mr. Aasen has also kindly revised the English text.

MATERIAL AND METHODS

In 1948 the author started regular investigations on the occurrence of eggs and larvae of spring-spawning fish in the coastal and bank areas

Fig. 1. The spawning area of the Arcto-Norwegian stock of cod. Cross-hatched: intensive spawning. Single-hatched: some spawning. Black dots: plankton stations worked during the spring in the years 1948—1956.

of northern Norway. The area in question is shown in Fig. 1. The sampling technique has been described earlier (WIBORG 1950), but will, however, be shortly repeated here.

Three Clarke-Bumpus plankton samplers (CLARKE-BUMPUS 1940) were attached to the hydrographical wire at intervals corresponding to vertical distances of 25 m during the towing. A weight of 32 kilogrammes was fastened at the end of the wire. The samplers were towed for 20 minutes in 5 steps between 75 m and the surface. Usually, 6—10 m^3 of sea water was filtered by each sampler. The samples were preserved with 5—10 % formalin. In the laboratory, all fish eggs and larvae were later sorted out, determined and counted, and the total number calculated below one square meter of sea surface. Preliminary results on the occurrence of fish eggs and larvae have already been published (WIBORG 1950, 1952, 1954, 1956).

Each year the stations in the Vestfjord, the Vesterålen area, and the Andfjord were usually visited twice; at the beginning of May, and at the end of May/beginning of June. In 1949 and 1951 the Vestfjord was also investigated at the beginning of April. At some stations additional hauls were made. In the present paper the material from the stations north of the Andenes—Egga section has been omitted.

VARIATIONS IN ABUNDANCE OF EGGS AND LARVAE DURING 1948—1956

As is generally known, the Vestfjord, and the coastal banks northwards to Sørøya (see Fig. 1) are the main spawning areas of the Arcto-Norwegian stock of cod. The spawning takes place from the end of January to the beginning of May, with the main period from the middle of March to the beginning of April. Fig. 2 shows the progress of spawning in 1956 at Skrova in the inner part of the Vestfjord.

The variations in the number of eggs and larvae during 1948—1956 are shown in Fig. 3. The data have been combined for two different areas, the Vestfjord (14—24 stations) and the Vesterålen banks and the Andfjord (14—22 stations).

At the beginning of May most of the cod eggs are hatched, and the samples usually contain 70—90 per cent larvae. In some years, however, the larvae at this moment only amount to 25—30 per cent, as will be shown later on.

The graphs for the two cruises largely follow the same pattern, with peaks in 1949, 1952 and 1955, and minima in 1950 and 1954. The June

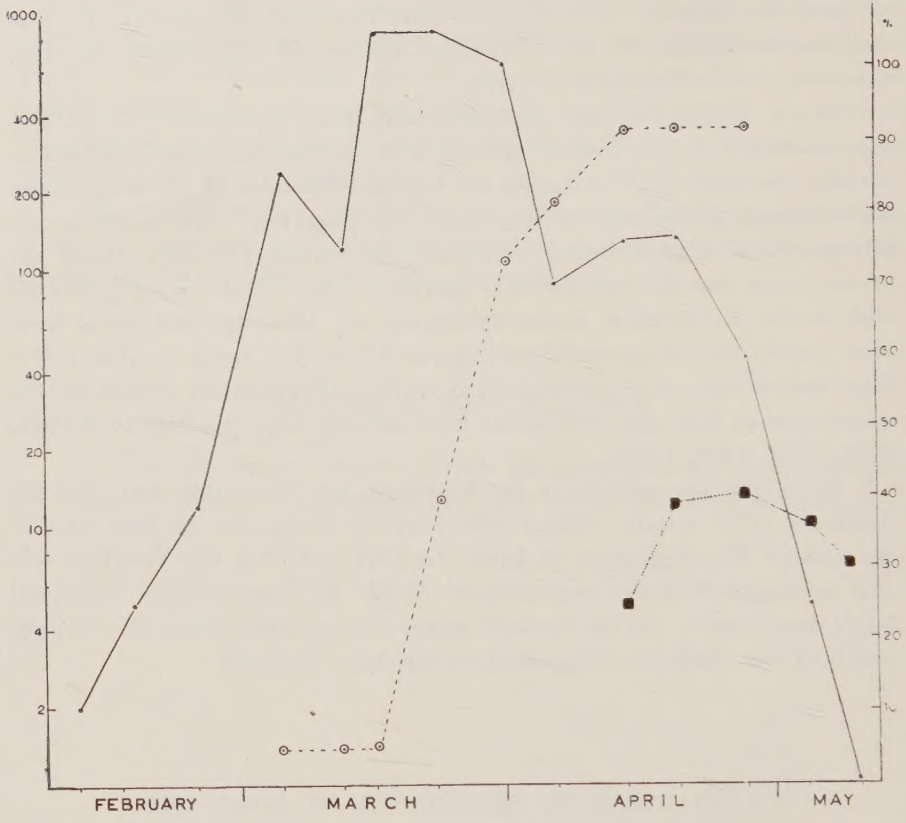

Fig. 2. Number of cod eggs (drawn) and larvae (dotted) in vertical hauls with a «8/70» Nansen net (left scale) and percentage of older stages of cod eggs (hatched, right scale) at Skrova February—May 1956.

minimum in 1950 was very pronounced, with only 1.1 larvae per m^2 of sea surface.

According to Maslov (1956) and Sætersdal (1956), the bulk of the commercial catches of cod in the Barents Sea and on the Finmark coast during the three last years consisted of the 1948—1950 year classes. Fig. 4 has been reproduced by the courtecy of Mr. Sætersdal.

The 1950 year class dominates, with the 1949 and 1948 year classes ranking second and third respectively. The 1951 year class seems to be of minor importance. The year classes 1948 and 1949 made their appearence in the Finmark spring fisheries at an age of 4 years, the 1950 year class already 3 years old. The 1951 year class appeared already as 3 years old, but the yield was small both in the 4th and 5th year. In hauls

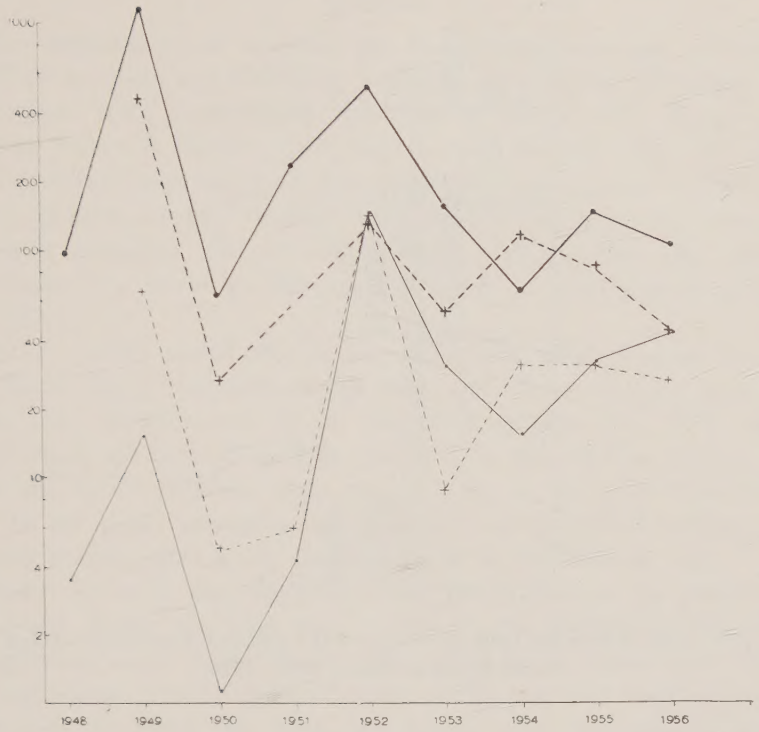

Fig. 3. The number of cod eggs and larvae per square meter of sea surface in the Vestfjord (drawn curves) and in the Vesterålen and Andfjord areas (hatched curves) during the spring of the years 1948—1956. Upper heavy curves; at the beginning of May; lower thin curves; at the end of May/beginning of June. Logarithmic scale.

with a fine-meshed trawl in the Barents Sea during the years 1947—1955 (MASLOV 1956) the year class 1952 was poorly represented as 0—II groups, while the 1948—1951 and 1954 year classes can be characterized as medium or rich.

From these data it is evident that little or no positive correlation exists between the number of cod eggs and larvae in the spawning area at the beginning of May or 3—4 weeks later, and the size of the corresponding year classes in the commercial catches. On the contrary, the rich year classes 1948 and especially 1950, were characterized by a minimum number of eggs and larvae. It is therefore necessary to search for other factors which may influence the survival of the cod larvae at a later stage of development, *i. e.*, during, or after they have left the spawning area on their drift northwards to the nursery grounds of the Barents Sea and the Bear Island—Spitsbergen banks.

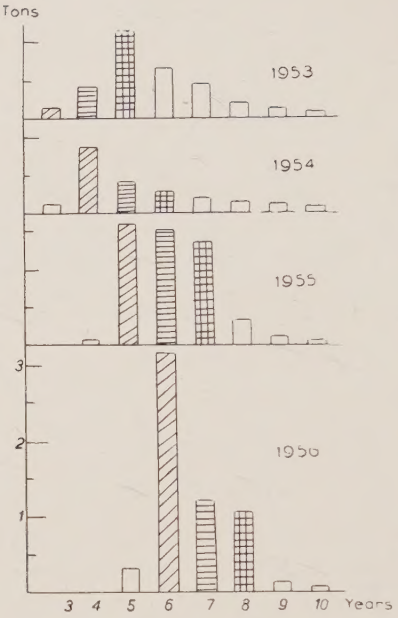

Fig. 4. The catch in tons per man per season of the different year classes of cod in the Finmark spring fishery 1953—1956.

DISCUSSION

Factors Affecting the Survival of the Larval Stages

Of the factors which are of importance for the survival of the larval stages of fish, especially the Arcto-Norwegian stock of cod, some of the most important ones are thought to be the temperature conditions in the spawning area, variations in the extension of this area, the direction and strength of the currents carrying the larvae away from the area, and other conditions which indirectly may be of importance for the distribution of the larvae, such as the length of the spawning period, moment of hatching, etc.

Temperature

The Arcto-Norwegian cod usually spawns at a temperature between 4° and 6° C., and, as stated earlier, (p. 7), the usual spawning area extends northwards to Sørøya. A little spawning takes place farther north, in warm years even along the Murman coast (Maslov 1944). Lee (1956) also infers that a small rise in temperature would increase the effective area of the spawning grounds and displace the centre of spawning northwards.

Currents

The importance of currents for the distribution and survival of larval fish has been emphasized by a number of scientists (Walford 1935, Carruthers 1938, Carruthers, Lawford & Veley 1951, Carruthers, Lawford, Veley & Parrish 1951, Chase 1955, Fraser 1956). An otherwise successful brood may not grow up to the bottom stage on the usual feeding grounds because currents have carried the larvae to other, less favourable localities. On the other hand, currents may also increase the chance of survival in carrying the larvae to good nursery grounds (Lee 1956).

Marti (1956) stated that in the Atlanto-Scandian herring the rich year classes had a reduced growth rate, and *vice versa*, the poor year classes were characterized by an increased growth rate. This phenomenon could not be explained by crowding in the feeding areas, as this would also affect different year classes living at the same time in the area. In his paper examples are given of year classes of herring with different growth rates living simultaneously in the Barents Sea.

Marti came to the conclusion that the difference in growth was determined during the first year of life by the drifting of the larvae into different areas of the Barents Sea. The larvae which gave way to rich year classes were distributed more to the east and north where the temperature is lower, the poor year classes were concentrated in the warmer western parts.

Rollefsen (1954) states that there are great variations in growth rate of different year classes of cod, but ascribes this to varying degrees of crowding in the feeding areas. However, Maslov (1956) reports that the 1949 year class of cod which has proved to be above medium size, was taken as 0-group in the easternmost parts of the Barents Sea, and did not appear in the western parts until later on, as I—II groups.

Variations in Size of the Year Classes in Relation to the Biological Conditions during the Early Life History

On the assumption that an effective transport of the cod larvae to the feeding areas in the Barents Sea and adjacent areas, and a wide dispersal in these areas would be favourable for the development of a rich year class, we may consider which conditions would favour such a dispersal. The following factors are considered to be of major importance:

1) an extensive spawning area,
2) a long spawning period,
3) a long hatching period,
4) strong northgoing currents during the drift of the eggs and larvae.

Spawning Area

An extension of the spawning area of the cod, or a northwards displacement of the centre of spawning would increase the chances for a wide dispersal of the brood. Unfortunately, observations on the variation of the spawning area are scarce, but some information is available. At the end of May 1948 comparatively many small cod larvae were found on the Malangsgrunnen and Svein-grunnen banks. (See Fig. 6, p. 19). These larvae probably originated from a spawning not far away. In early May 1954 there were more cod eggs and larvae per m^2 on the Vesterålen banks than in the Vestfjord. (See Fig. 3, p. 9). Some conclusions may also be drawn indirectly. When eggs and larvae of haddock and saithe, which usually spawn farther south (DAMAS 1909. SÆTERSDAL 1952) occur in the Lofoten area, it is to be expected that the spawning area of the cod would extend further northwards. *Vice versa*, the spawning of cold water species, (e. g. capelin) farther south than usual, may indicate a restriction of the spawning area of the cod.

In 1948 eggs and larvae of haddock were taken in moderate numbers on the Vesterålen banks. In 1949, 1950 and 1951 the southwestern border of the spawning area of the capelin gradually moved from the North Cape area right to the Lofoten Islands. In 1951 the temperature of the upper 50 m layer on the Vesterålen banks was 3.5°—4.5° C., in March—April of the preceding year between 4.5° and 5.5° C. (WIBORG 1952). In 1952 and 1953 the western limit of the spawning area had again withdrawn to the North Cape area.

In 1954 haddock eggs and larvae were again found in the Lofoten area in moderate numbers. Simultaneously eggs and larvae of saithe occurred. Accordingly it may be assumed that the main spawning area of cod in 1948 and 1954 extended northwards, while in 1951 the area was somewhat restricted.

On the northernmost banks plankton hauls have only been taken in the middle of May. Cod eggs and larvae, although scarce, were always found, and the figures do not indicate such variation as might be expected.

Spawning Period

Some information with respect to the length of the spawning period may be obtained from the Fishery Statistics of Norway (1948—1956). Data are available on the quantities of fish and cod roe for each week of the Lofoten fishery. During the first part of the fishery there is usually a constant relation between the weight of fish and the amount of cod roe landed. But as the cod begin to spawn, the quantity of roe

decreases. The beginning of the spawning period will therefore be characterized by an increase in the relation: fish weight/roe weight. When the quantity of roe goes to zero, the spawning is supposed largely to decrease, unless other factors, such as prohibition of salting of cod roe may put an end to the landing of roe. This was the case in 1952 and 1953.

More reliable information on the spawning period can be obtained from plankton hauls. Unfortunately, plankton hauls during the whole spawning season have only been taken in one locality, at Skrova in the inner part of the Vestfjord, during 1949—1951 and 1955—1956. The probable length of the spawning period has been calculated. (Table 1).

Table 1. *The Length, and Date of Ending of the main Spawning Period of the Cod in the Lofoten Area during the Years 1948—1956, calculated from the Fishery Statistics and from. Plankton Hauls.*

Year	Spawning period in days		End of spawning	
	Fish. l. St.	Pl. hauls.	Fish. l. St.	Pl. hauls.
1948	42	—	17.IV	—
1949	42	30—40	23.IV	16.IV
1950	42	50	22.IV	25.IV
1951	21	20—30	4.IV	17.IV or later
1952	– – – – –	no data	– – – – – – – – – –	
1953	– – – – –	no data	– – – – – – – – – –	
1954	21	—	17.IV	—
1955	21	21	23.IV	30.IV
1956	42	40	14.IV	20.IV

There is a reasonable good correlation between the data from the fishery statistics and the plankton hauls. The end of the spawning as a rule seems to occur later, when calculated from the plankton hauls. The reason for this is that the Lofoten fishery often ends before all the fish have moved away from the spawning area.

The years 1948—1950 and 1956 are characterized by a long spawning period of 40—50 days, the years 1951, 1954 and 1955 by shorter periods of 20—30 days. The spawning generally seems to have ended between 15 and 25—30 April.

Hatching Period

A prolonged hatching period may be advantageous for the survival of the larvae and increase the effect of a long spawning period. The eggs will be dispersed over a wide area before hatching.

All the mature fish does not come to the spawning area at once. The older fish, which have spawned in earlier years, arrive first, the

younger first time spawners at the end of the season. This is also evident from the variation in abundance of the eggs at Skrova (Fig. 2, p. 8). A comparatively high percentage of eggs at the end of the spawning season may therefore as well indicate a strong influx of late spawners, as a retarded hatching caused by external factors, e. g. low temperature. It will nevertheless be of interest to compare the percentage of cod larvae in relation to eggs in the plankton hauls in the spawning area at the beginning of May in the different years. (Table 2).

Table 2. *The Percentage of Cod Larvae at the Beginning of May of the Years 1948—1956 in the Vestfjord and on the Vesterålen Banks.*

Year	1948	1949	1950	1951	1952	1953	1954	1955	1956
Vestfjord	32	85	26	33	85	73*	76	20	88**
Banks	—	86	36	82	66	43*	78	55	88**

* 11—19 May. ** 8—15 May.

The years 1948, 1950, 1955, and possibly also 1953 are characterized by a low percentage of larvae. In 1951 the percentage was low in the Vestfjord, but high on the banks. Observations are lacking on the banks in early May 1948.

Water Transport

According to Carruthers, Parrish, et al. (1951) a very high correlation exists between certain wind conditions in the North Sea during the spawning period of the haddock and the size of the corresponding year classes in the commercial catches. An attempt was therefore made to find if similar correlations could be traced for the Lofoten cod. The wind observations during the months March—June of the years 1948—1956 were studied and compared with the size of the corresponding year classes of cod as they appeared in the Barents Sea and Finmarken fisheries, but without success. It is assumed that the complex topography of the spawning area and the strength of the coastal current will outweigh the variations caused by wind.

In the Vestfjord the surface currents steadily run out of the fjord along the north western shores, then, turning to the west and north, continue north-eastwards, along the north-western shores of the Lofoten and Vesterålen Islands. The transport from the inner part of the Vestfjord to the entrance of the fjord is supposed to take about three weeks (Eggvin 1931, Wiborg 1950).

No calculations have yet been made of the variations in the amount of water transported from the spawning area north- and north-eastwards to the Bear-Island—Spitzbergen banks and into the Barents Sea in the different years. According to Lee (1952) there was an unusually strong influx of Atlantic water on the Bear Island banks in the summer of 1950.

Reduction in Number of Eggs and Larvae Caused by Water Transport and Natural Mortality

The influx of water transport of the cod larvae within the spawning area may be traced in an indirect way. We may once more return to the data of cod eggs and larvae presented in Fig. 3 (p. 9). During the years 1948—1951 there was a very pronounced reduction in the number of eggs and larvae from May to June. This reduction is caused partly by mortality, partly by the removal of eggs and larvae from the area by currents.

In June there is a certain percentage of larger larvae which are able to avoid plankton nets. The latter fact may lead to erroneous conclusions as to the size of the reduction, but the size distribution of the larvae taken may to a certain amount indicate the degree of dodging (see p. 19).

An attempt has been made to calculate the reduction per day of the number of cod eggs and larvae in the Vestfjord. Austnesfjord and Vesterålen areas during May in the years 1948—1956 (Table 3 and Fig. 5), from the formula $R = \frac{k \times 1000}{days}$ where $K = \text{Ln } N_1 - \text{Ln } N_2$.

In the Vestfjord the reduction was great during May in the years 1948—1951. Then it dropped suddenly in 1952, decreasing gradually to 1956. On the Vesterålen banks the reduction was much less, except in 1951, but there was also a decrease from 1953 to 1956. In 1952 the number of cod eggs and larvae increased on the Vesterålen banks during the two first weeks of May, probably because of an increased supply from other areas, presumably the Vestfjord, and/or a considerable local spawning.

The great reduction in the number of cod eggs and larvae in the Vestfjord during May in the years 1948—1951 may indicate a strong transport away from the area. On the Vesterålen banks a similar high reduction was only found in 1951. It is therefore assumed that the larvae to a certain extent are accumulated on these banks on their way north-eastwards, but spawning on the Vesterålen banks at the end of the season (first time spawners) may blur the picture.

In 1949 and 1951 plankton hauls were also taken in the Vestfjord at the beginning of April. Nearly all the samples then consisted of eggs.

Table 3. *The Reduction in total Number of Eggs and Larvae of Cod at identical Series of Stations in the Lofoten and Vesteralen Areas from April to May, and further to the End of May/Beginning of June, and the Reduction per day* $R = \frac{k \times 1000}{days}$ *where k is Ln* N_1 — *Ln* N_2.

Area	Year	Beg. of April	Beg. of May	End of May/Beg. of June	Interval in days	R
Vestfjord	1948	—	188	66	30	111
	1949	89391	21284	—	24	61
	1949	—	21284	280	30	144
	1950	—	1437	24	31	152
	1951	19259	5138	—	26	50
	1951	—	5138	80	24	174
	1952	—	9705	2287	14	102
	1953	—	3360	900	21	62
	1953	—	—	612	7	54
	1954	—	1522	352	26	55
	1955	—	2846	633	30	50
	1956	—	1941	785	24	38
Austnesfjord	1949	5588	—	28	63	84
	1951	—	658	126	26	64
	1953	—	631	275	20	41
	1954	—	173	39	24	62
	1955	—	579	137	32	45
Balstad section	1952	6945	2708	—	12	78
	1952	—	2708	845	17	69
Vesterålen—Andfjord	1949	—	1850	286	25	75
	1950	—	320	57	25	69
	1951	—	1395	139	17	135
	1952	—	2360	2729	13	—
	1953	—	1248	275	21	72
	1954	—	2160	576	18	74
	1955	—	1143	433	22	45
	1956	—	819	484	18	29

At the beginning of May 1949, 85 per cent of the eggs were hatched, at the corresponding time in 1951, 33 per cent only. As the reduction was very near the same in the two years (the open squares in Fig. 5) there is apparently no increased mortality during hatching. It is stressed that some spawning usually takes place during April, and the reduction may therefore be somewhat greater than indicated in the figure.

In 1952 a cross section of the Vestfjord, at Balstad, was investigated three times, April 21, May 3, and May 20. The percentages of larvae were respectively 24.5, 85 and 100. The reduction was of nearly the same

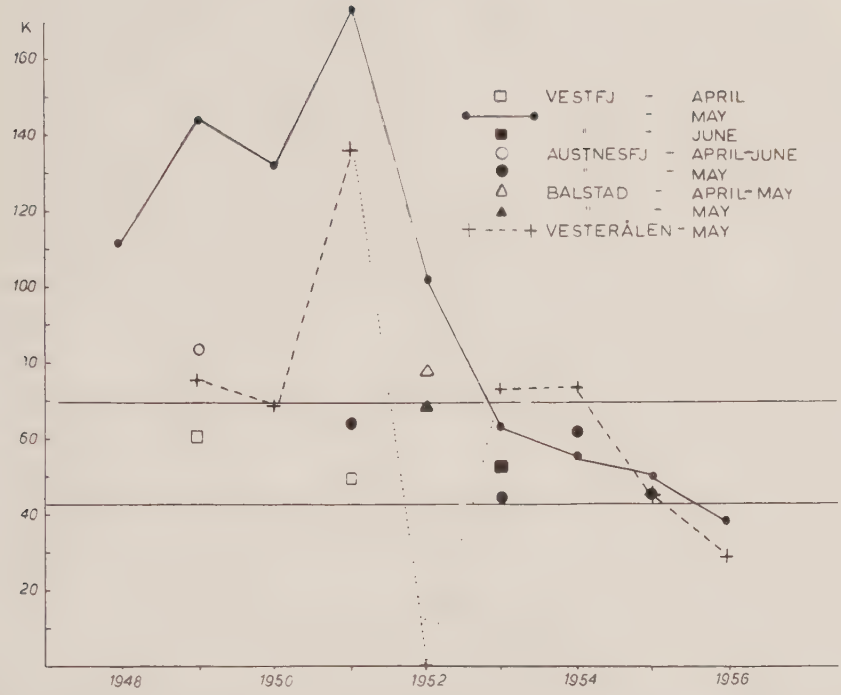

Fig. 5. The reduction (R) per day of the number of cod eggs and larvae at identical series of stations in the Vestfjord and Vesterålen areas during April—June 1948—1956.

size as from eggs to larvae in 1949 and 1951. Observations from two cruises with an interval of one week covering the whole Vestfjord at the beginning of June 1953, show reduction of a similar size.

The Austnesfjord is a small fjord situated in the inner part of the Vestfjord (Fig. 1, p. 6), where currents are supposed to be of little importance for the removal of cod eggs and larvae. In 1949 and 1951 the reduction here was very low compared with that for the Vestfjord in the same years. In 1953—1955 the reduction was of the same order of size. The figures may therefore be considered as an expression of the natural mortality (cp. also p. 18). The figure for 1949 covers an interval of two months.

In 1951, 1953, and 1954, 78—87 per cent of the eggs had been hatched at the beginning of May, in 1955, 29 per cent only. As the reduction was only slightly smaller in 1955, this may be a further indication that the mortality is not particularly increased during the hatching. According to Dannevig & Hansen (1952) practically no mortality exists in eggs of cod hatched artificially.

Size of the Larvae

All the cod larvae taken during the cruises at the end of May/beginning of June have been measured. Percentage curves have been constructed for the Vesterålen banks, the Vestfjord and the Austnesfjord (Fig. 6). The number of larvae measured usually exceeded a hundred, except in the Austnesfjord in the years 1948—1950 and 1954, and on the Vesterålen banks in 1950, when only 20—30 specimens were measured on each occasion. These curves are therefore not fully representative. In 1952 the observations were taken 8—14 days earlier than in the other years, and the figures are therefore not comparable with the others.

There is a great deal of variation in the size distributions from one year to another. In the Vestfjord the larvae were somewhat larger in 1948, 1949, 1951 and 1954 than in the other years. On the Vesterålen banks the largest larvae were taken in 1950 and 1951.

In 1948 the cod larvae were much larger in the Vestfjord than on the Vesterålen banks. The great reduction in number from May to June mentioned above (p. 15), may therefore very well be caused by a high degree of dodging. However, in 1954 the larvae were also comparatively large in the Vestfjord, but the reduction small (see Fig. 5, p. 17).

In the Austnesfjord the larvae were usually a little smaller than in the Vestfjord, but the difference found in 1951 does not explain the large difference in reduction in the two areas. It must therefore be assumed that the great reduction in number of cod eggs and larvae from May to June in the Vestfjord during 1948—1951 stated above (p. 15), was mainly caused by an increased transport out of the fjord by currents.

At the beginning of May there are generally fewer eggs and larvae per m^2 of sea surface on the Vesterålen banks than in the Vestfjord (see Fig. 3, p. 9). The only exception was the year 1954. At the end of May/beginning of June, however, we have the opposite relation, with some exceptions. A considerable spawning usually takes place on the Vesterålen banks. Local eddies may exist north of the Lofoten Islands and in the Andfjord, but on the whole the currents run in a north-eastward direction. The eggs and larvae will therefore be continuously carried away, and it is likely that the majority of the larvae found here at the end of May/beginning of June usually have been introduced from other areas, presumably the Vestfjord. The ratio between the number of cod larvae per m^2 of sea surface on the Vesterålen banks and in the Vestfjord at this moment may give an indication of the transport of larvae away from the Vestfjord and north-eastwards along the coast. This is shown in Table 4. The plankton hauls in the two areas have been taken with intervals of 2—5 days, and should therefore be comparable. In 1952 the observations may have been taken too early.

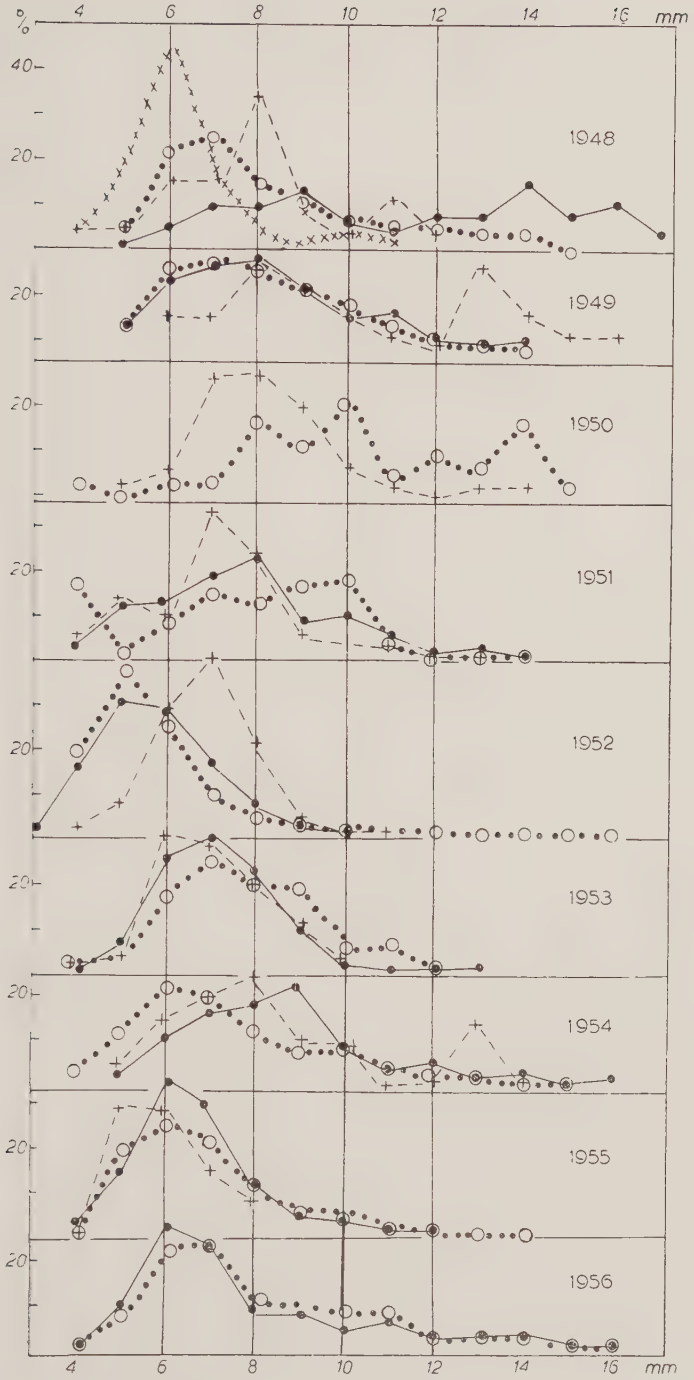

Fig. 6. The size distribution of the cod larvae in the Vestfjord (drawn), Austnesfjord (hatched), Vesterålen and the Andfjord (dotted) and Malangsgrunnen (crosses) at the end of May/beginning of June 1948—1956.

Table 4. *The Ratio between the Number of Cod Larvae per m² on the Vesteralen Banks and in the Vestfjord at the End of May/Beginning of June 1948—1956.*

Year	1948	1949	1950	1951	1952	1953	1954	1955	1956
Ratio	3.5	4.6	4.4	1.4	(0.9)	0.3	2.0	1.0	0.6

During the years 1948—1951 and 1954 there were more larvae per m² of sea surface on the Vesterålen banks than in the Vestfjord at the end of May/beginning of June. If the figures in Table 4 express the degree of north-eastward transport of the larvae, one gets the following order of rank for these years: 1; 1949, 2; 1950, 3; 1948, 4; 1954, 5; 1951. There are some exception to the figures for 1948 and 1954. From the length distributions (Fig. 6, p. 19) it appears that the larvae on the Vesterålen banks in June 1948 and 1954 were smaller than those in the Vestfjord. This may indicate that some of the larvae are of local origin.

CONCLUSIONS

Of the factors mentioned above, the transport of eggs and larvae from the spawning areas to the nursery grounds in the Barents Sea and adjacent areas is probably of greatest importance for the abundance of a rich year class. But in addition, other conditions, such as the number and kind of predators, the food organisms available, and the physical and chemical properties of the surrounding medium, are undoubtedly of great importance for the survival of the cod larvae.

In Table 5 the information arrived at in the preceding chapter has been compiled.

Table 5. *The Occurrence of Conditions assumed to be advantageous for the Development of rich Year Classes in the Arcto-Norwegian Stock of Cod during 1948—1956.*

Year class	1948	1949	1950	1951	1952	1953	1954	1955	1956
Long spawning period	+	+	+	—	?	?	—	—	+
Late hatching and/or additional spawning late in the season	+	—	+	+	—	+	—	+	—
Strong northward transport deduced: a) from the reduction (Fig. 5)	+	+	+						
b) from number of larvae in the different areas in June (Table 4)	(+)	+	+	+	—	—	(+)	—	—
Northward displacement of the spawning centre	+	—	—	*	—	—	+	—	—

* possibly reduction of the spawning area.

The years 1948—1950 apparently fullfill a number of the conditions assumed to be advantageous for establishing a rich year class. The years 1951 and 1954 come next, while the remaining years have only one positive character or none at all.

As mentioned earlier (p. 8) the year class 1950 dominates the commercial catches in the Barents Sea, followed by 1949 and 1948. The 1951 year class is probably of medium size or below. The year class 1952 was characterized by MASLOV (1956) as poor, because it was very poorly represented in the catches of the 0-group in the Barents Sea, while the 1954 year class may appear to be of medium size.

It must be considered as proved that no correlation exists between the number of eggs and larvae during the months May—June and the size of the corresponding year classes in the Arcto-Norwegian stock of cod.

PARRISH (1950) stated that in the North Sea haddock the mortality of the 0-group, after the larvae had settled on the bottom, was not essentially different from that of the older fish.

MASLOV (1956) found a positive correlation between the number of the 0-group of cod and the size of the corresponding year classes in the commercial catches. It seems therefore probable that the size of the year classes must be determined during the drift of the pelagic stages from the spawning area to the nursery grounds, or immediately after the young fish have settled on the bottom.

It might be of some interest to make a rough calculation of the total number of eggs and larvae present in the spawning area at the beginning of May, especially in a year with a minimum stock of eggs and larvae.

The Vestfjord approximately covers an area of 6.6×10^9 m^2, the outer banks northwards to Sørøya, inclusive of the Andfjord, 59×10^9 m^2. In 1950, there were 50 eggs and larvae per m^2 in the Vestfjord, and 27 eggs and larvae per m^2 on the outer banks at the beginning of May. This would give a total of 2×10^{12} eggs and larvae. In addition come the eggs and larvae which have been carried away from the area earlier the season, and the possible additional spawning during May.

According to HJORT & PETTERSEN (1905) the pelagic stage of the cod lasts for about three months. If the mortality during this period is of the same size as in the Austnesfjord, with a reduction factor R of say 50 (cp. Table 3, p. 16) the total stock of larvae at the beginning of the bottom stage would be reduced to appr. 2.6×10^{10}.

There are no data available on the mortality of the immature cod, nor on the total yield of the different year classes in the Barents Sea fisheries. According to ROLLEFSEN (1954) the mortality of the mature cod is on an average 48 per cent per year, and the richest year classes have yielded about 24 millions of mature cod or skrei. Assuming a

fishing intensity of 25 per cent (DANNEVIG 1953), the total stock of mature cod would then be appr. 1.0×10^8 individuals. The mean age of the mature cod is 10 years.

During 10 years a yearly mortality of 48 per cent would reduce a stock of 2.6×10^{10} cod to 3.6×10^8 individuals. Whether these figures can be applied to the cod of the Barents Sea during the first 10 years of life, cannot yet be ascertained.

SUMMARY

1. The quantitative occurrence of eggs and larvae of the Arcto-Norwegian cod in the coastal and bank areas of northern Norway during the years 1948—1956 has been studied.

2. There is no correlation between the abundance of eggs and larvae and the relative strength of the corresponding year classes of cod in the commercial catches.

3. There is no increased mortality at any stage in the early life history of the cod.

4. The following conditions seem to be of importance for establishing a rich year class: a) a long spawning period, b) a prolonged hatching or spawning late in season, c) an extention or northward displacement of the spawning centre, d) a successful transport of the eggs and larvae from the spawning area to the nursery grounds by currents.

These conditions seem more or less to be fullfilled for the year classes 1948—1950, which now dominate the commercial catches in the Barents Sea and adjacent areas.

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